Simulation of a Periodic Jet in a Cross Flow with a RANS Solver Using an Unstructured Grid

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Outline

- The codes
  - Flow Solver
  - Grid generation
- Geometry - simplifications and grids
- Flow Model
  - Initial and inflow conditions
  - Diaphragm boundary condition
- Numerical results
  - Tuning the jet
  - Some observations

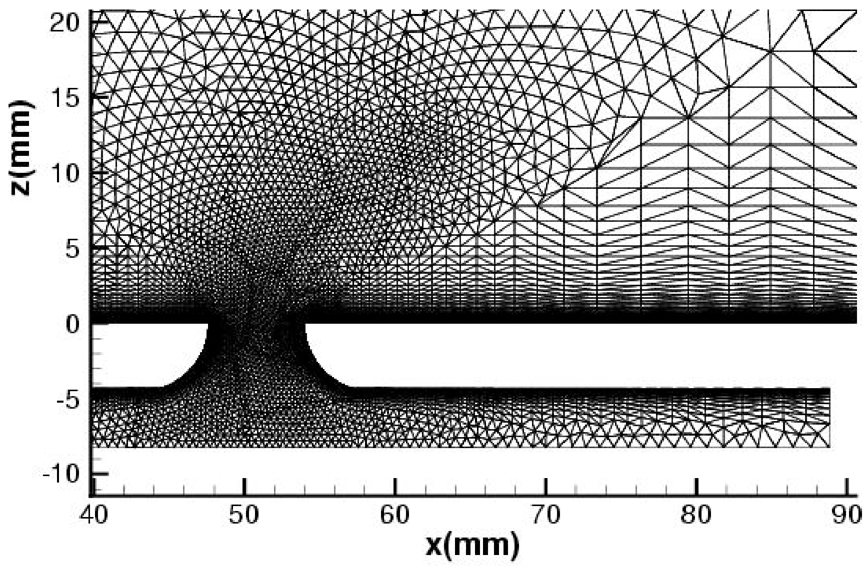
The Codes - Flow Solver

- FUN3D -- originally developed by Kyle Anderson
- Used primarily for analysis and design of steady aerodynamic flows
- Vertex-centered, unstructured grid
- 2nd-order, finite-volume
- Least-square + Roe flux-difference splitting
- Green-Gauss gradients
- Spalart-Allmaras turbulence model
- Implicit 2nd-order backward in time
- Solved by relaxation in pseudo-time
- Currently developed by the FAAST team
- Under continuous development

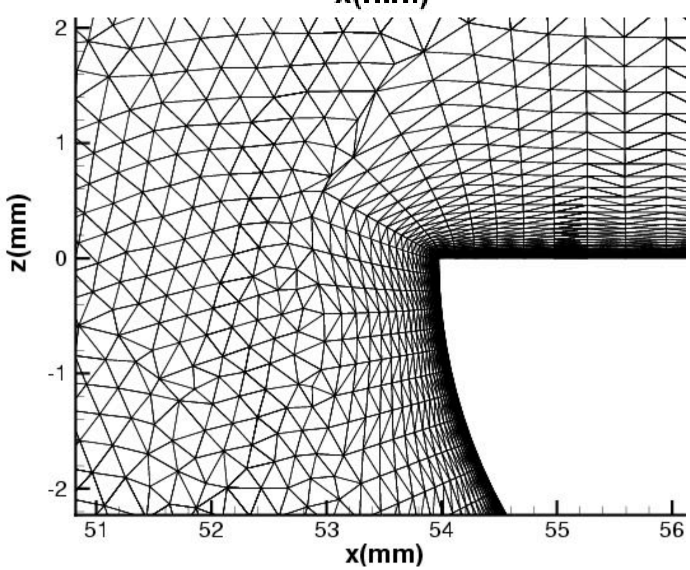
The Codes -- Grid Generation

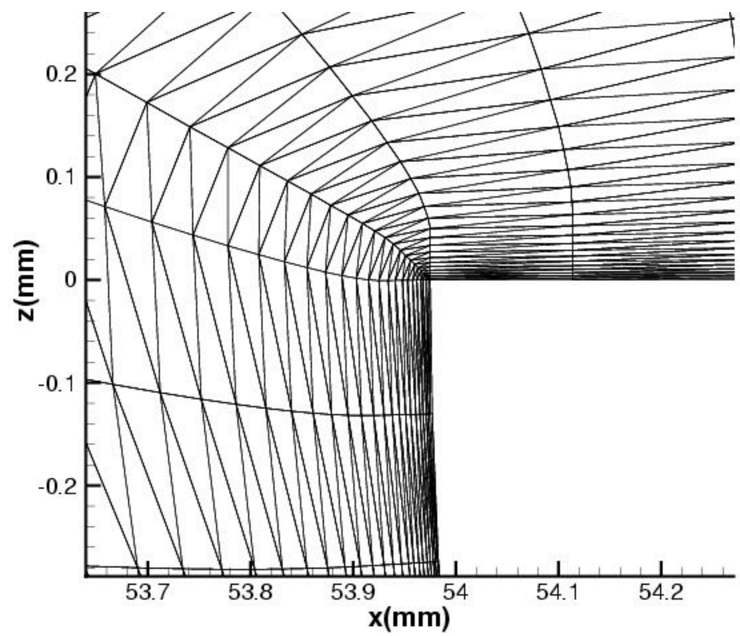
- GridEx -- Development led by Bill Jones
  - CAD access, surface and inviscid grid
  - Spacing controlled by sources
- MesherX -- Development led by Mike Park
  - Grows viscous layers from a given surface mesh
  - Provides control for spatially varying
    - First spacing
    - Growth rate
    - Layer termination

The Geometry -- Simplifications and Grids

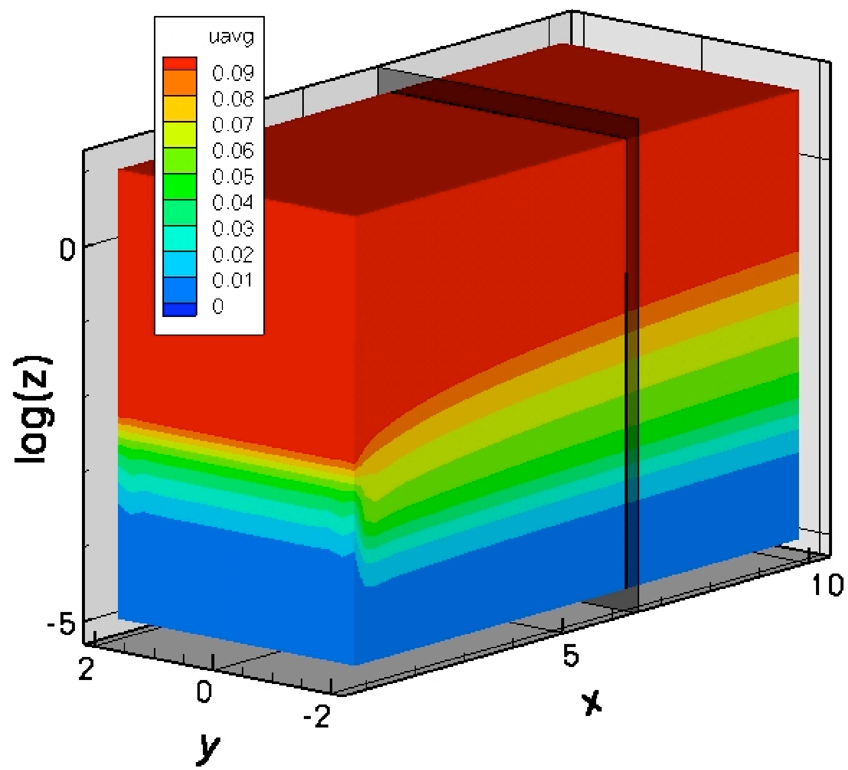


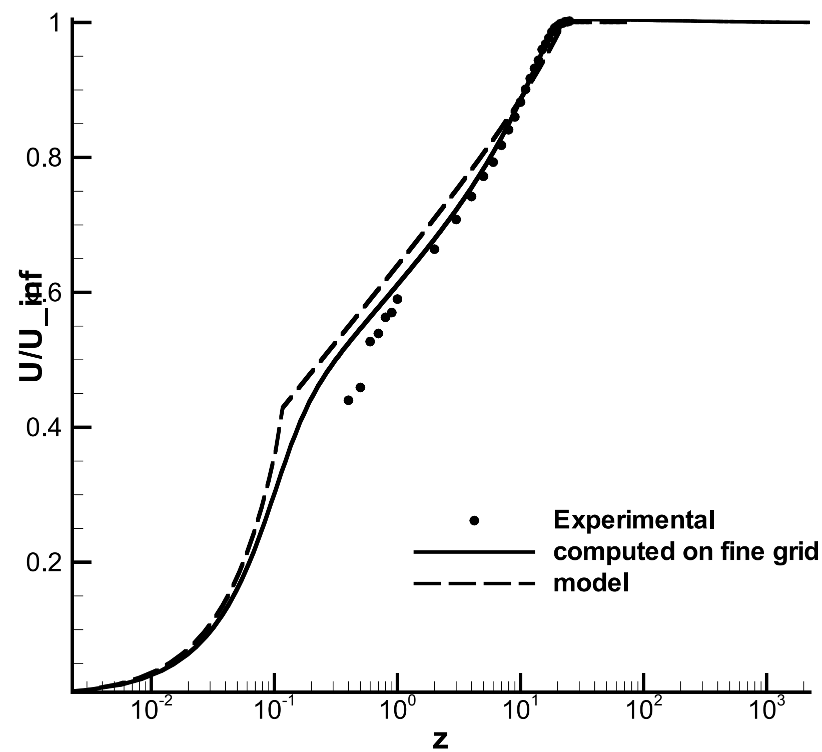
- Minimize the problem size
- Impose symmetry
- Flatten diaphragm
- Fine grid: 255426 nodes
- Medium grid: 46063



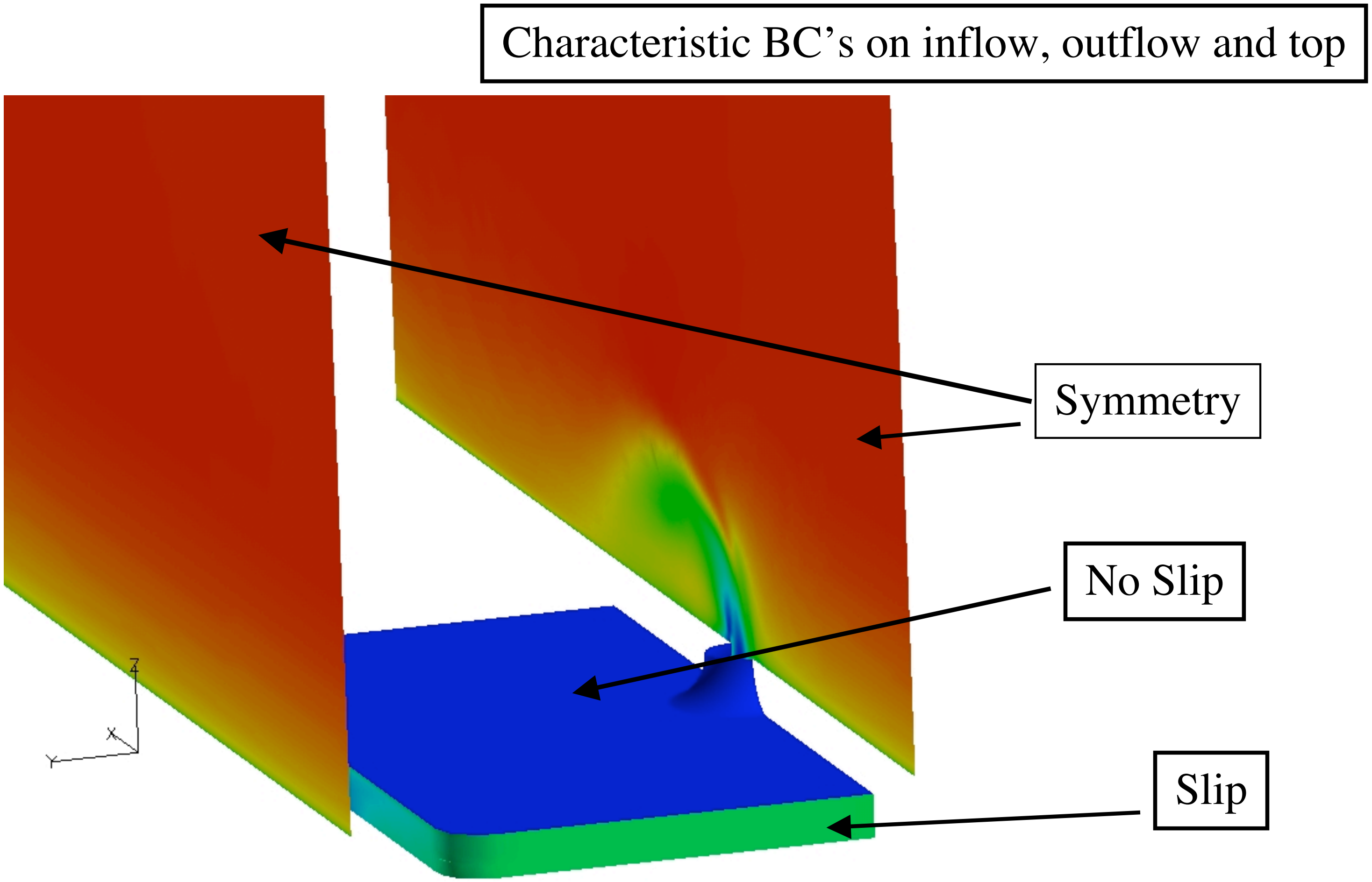


The Flow Model -- Inflow and Initial Conditions





Boundary Conditions

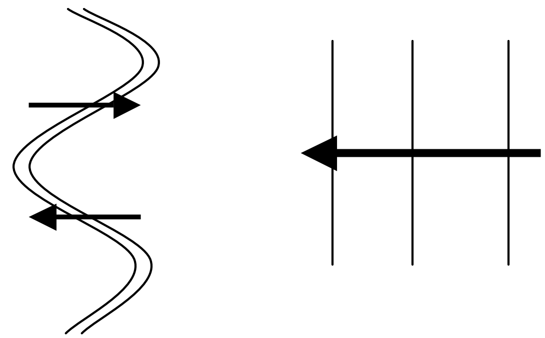


Piston Boundary Condition

Typical Characteristic BC

Unknown
U_b

Known
interior
U_i



Given
exterior
U_p

$R^+(U_b) = R^+(U_p)$ $\quad$ $R^-(U_b) = R^-(U_i)$

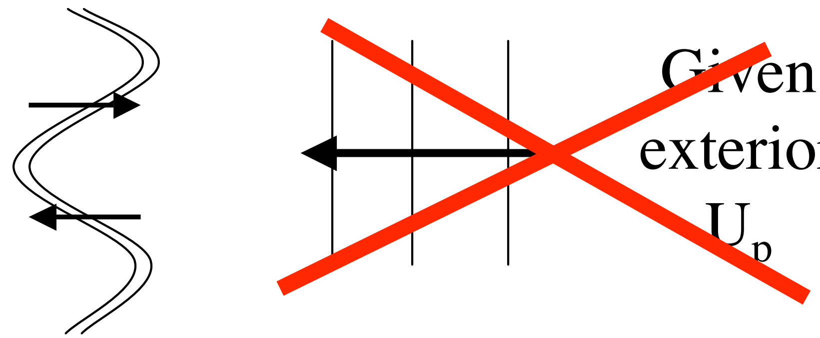
$R^c(U_b) = R^c(U_{p \text{ or } i})$

Piston Boundary Condition

Partially given

$V_b = \square \sin(\square t)$

Known interior U_i



$R^+(U_b) = R^+(U_p)$

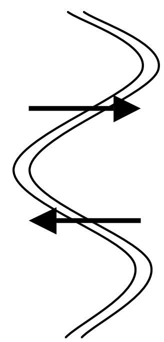
$\cancel{R^-(U_b) = R^-(U_i)}$

$R^c(U_b) = R^c(U_{\cancel{p\ or}\ i})$

Piston Boundary Condition

Partially given
$V_b = \square \sin(\square t)$

Known interior U_i



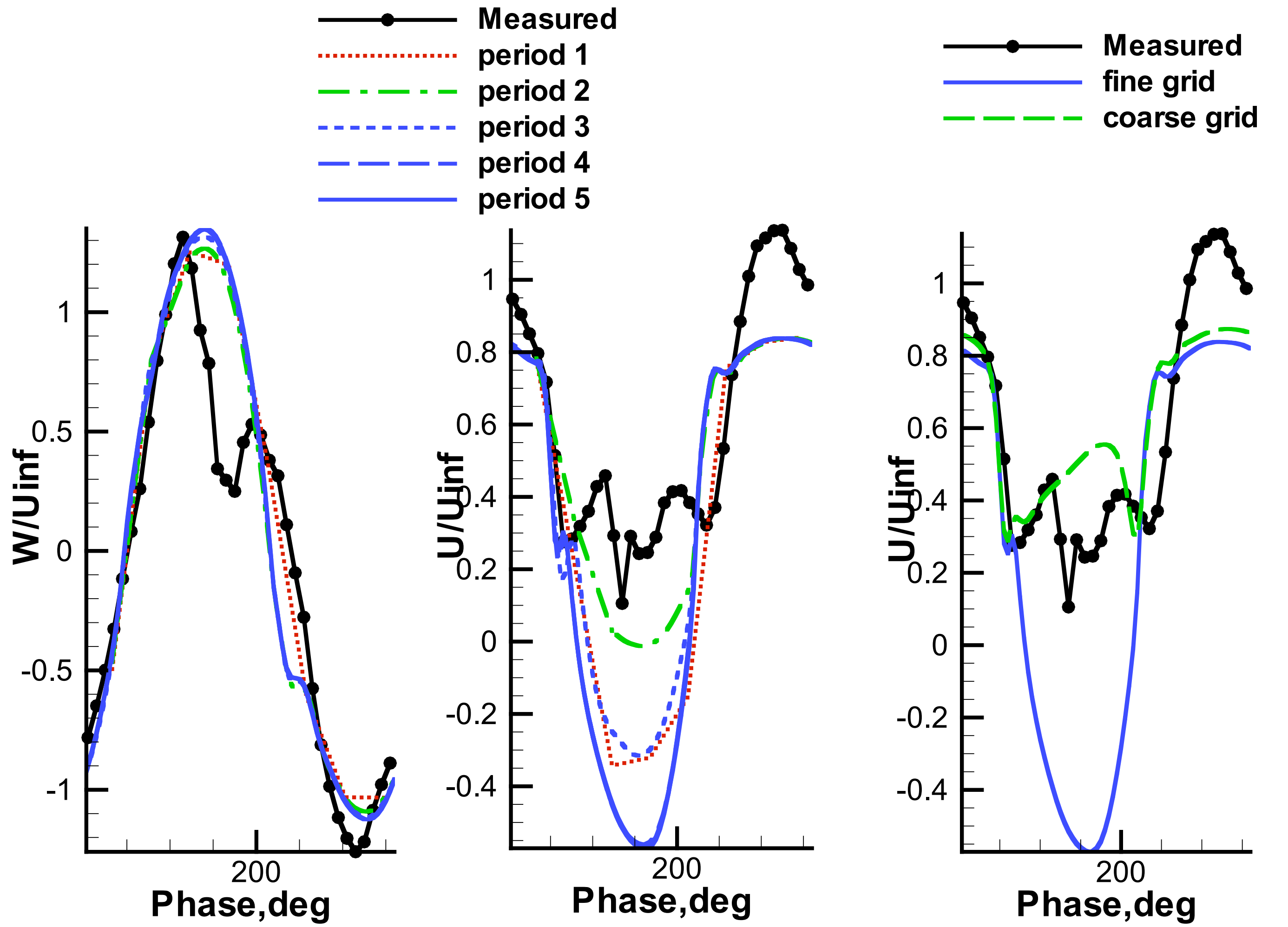
$R^c(U_b) = R^c(U_i)$

$R^+(U_b) = R^+(U_p)$

$R^c(U_b) = R^c(U_s)$

$$\boxed{\mathbf{V_n \gg V_t}}$$

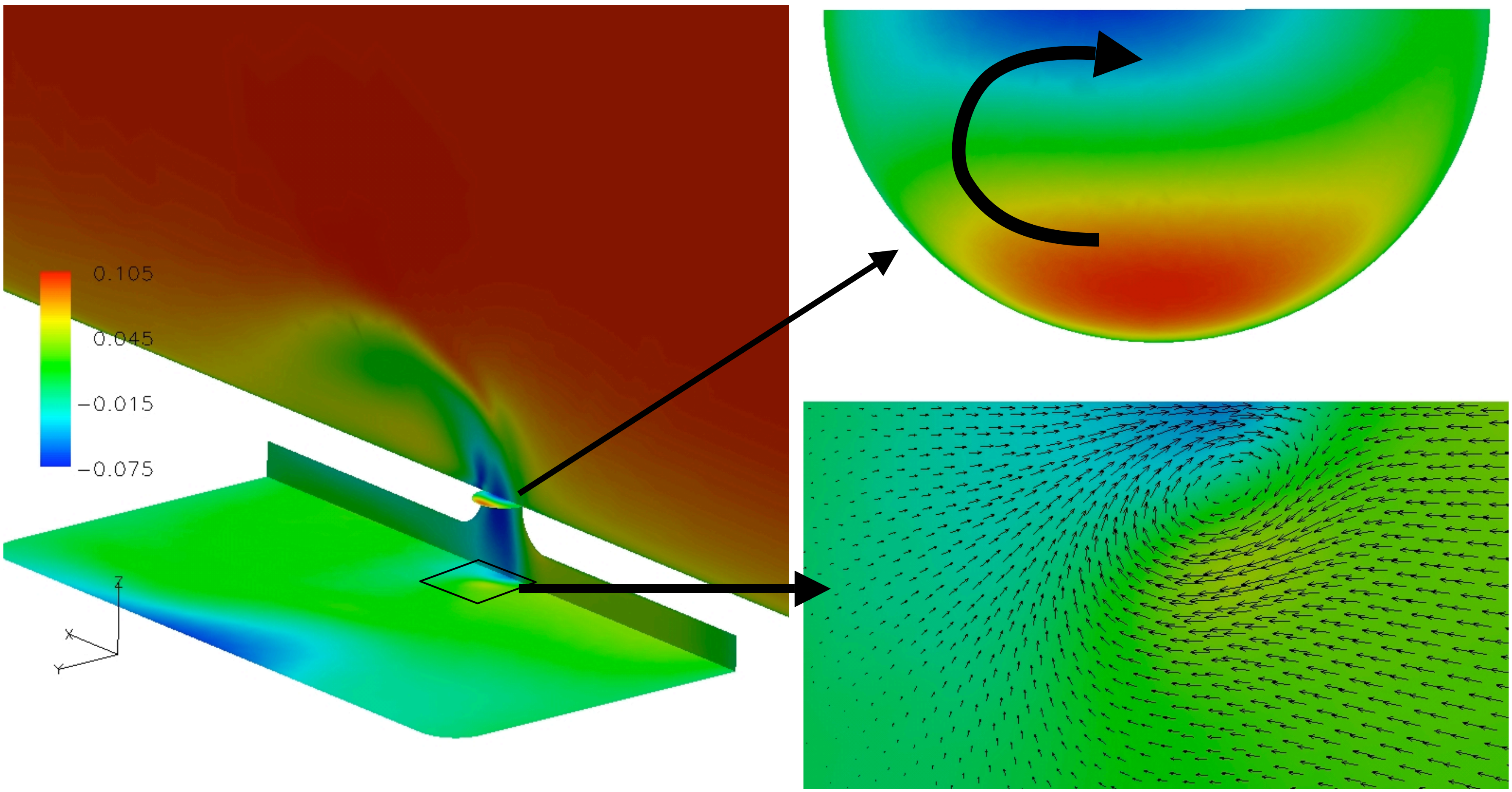
Numerical Results -- Tuning the Jet



720
20
5

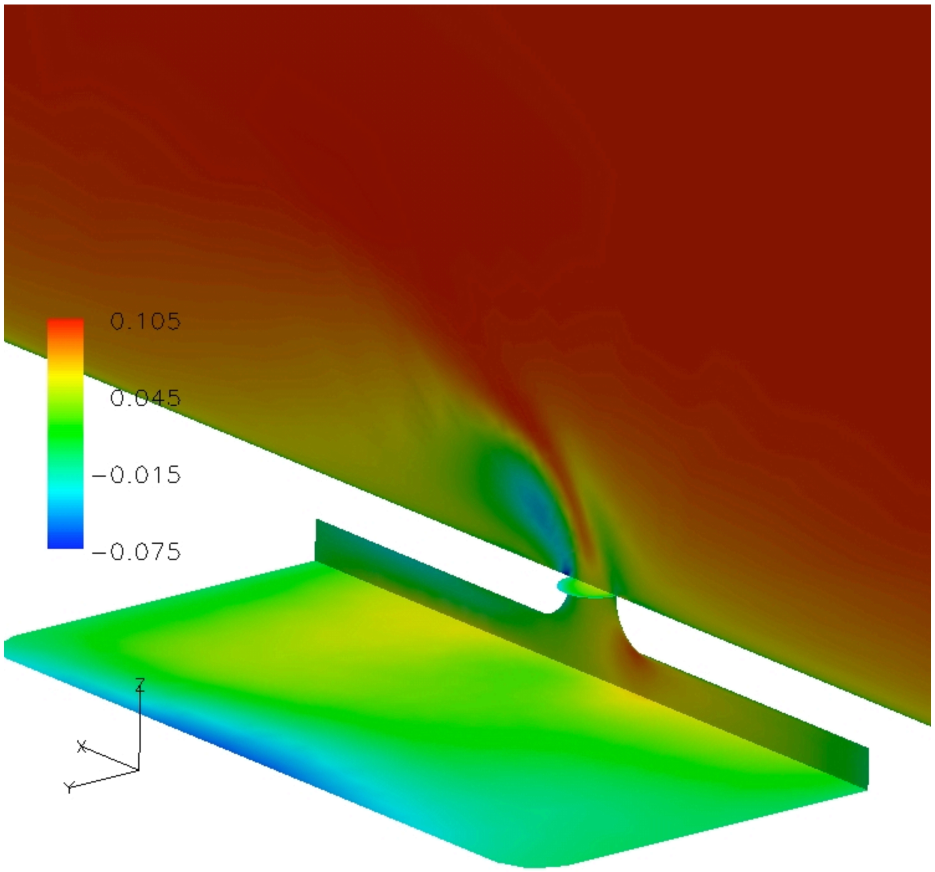
Some Observations

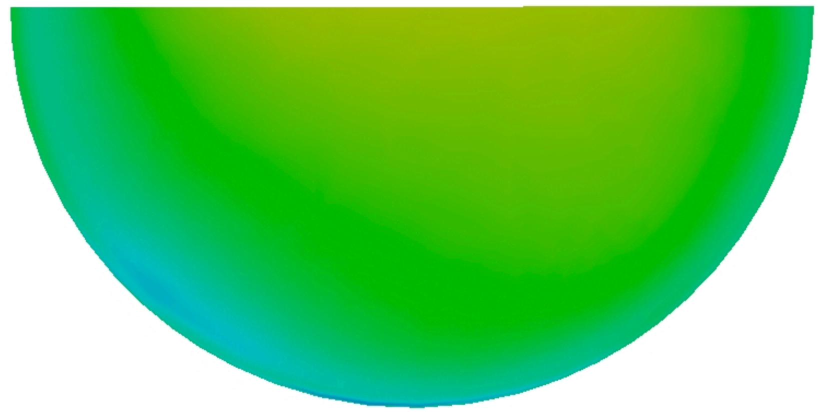
Fine grid: U/U_inf at phase = 160

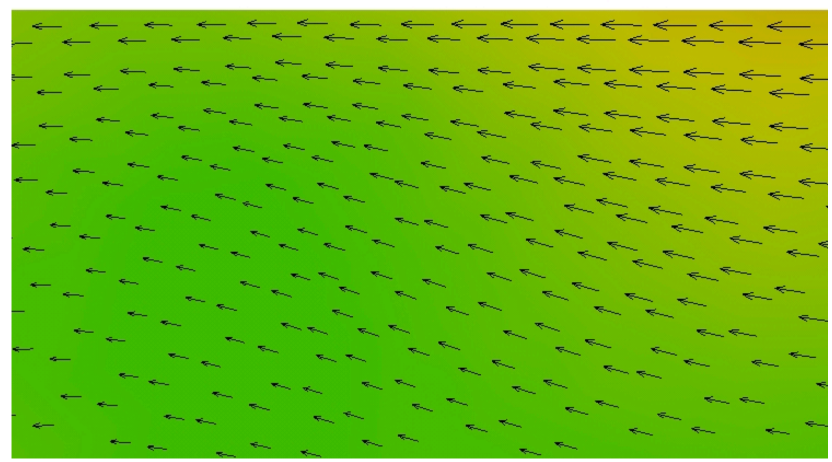


Some Observations

Coarse grid: U/U_inf at phase = 160

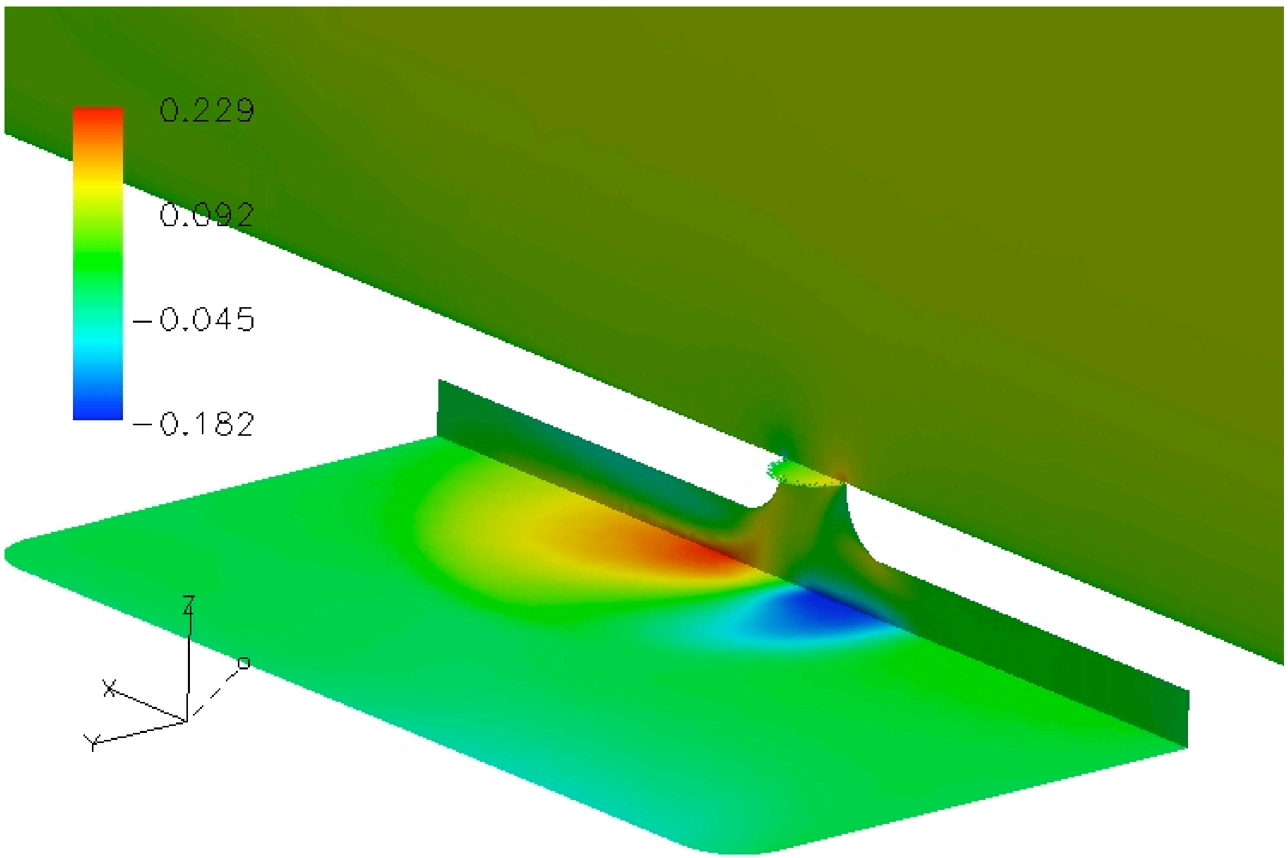






Some Observations

Fine grid: U/U_inf at phase = 320



Conclusions

- □V/V = □(1)
  - Dynamic flow in cavity
  - Model diaphragm on stationary boundary????
- Large difference between coarse and fine grids
  - Grid convergence????
- Vortical structures in cavity not surprising
  - Large v-component observed in the experiment could be due to an asymmetric vortical structures
- Imperfect symmetry of experiment introduces a wildcard